DOCUMENT RESUME

ED 132 716 EA 009 015

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TITLE Solar Guide and Calculator.
INSTITUTION Oregon Univ., Eugene. School of Architecture and Allied Arts.
PUB DATE Jun 76
NOTE 27p.; Parts of text may be marginally legible due to small type; This guide was developed by Center for Environmental Research
AVAILABLE FROM Center for Environmental Research, University of Oregon, Eugene, Oregon 97403 ($3.00)

EDRS PRICE MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS *Climatic Factors; *Environmental Influences; *Solar Radiation

ABSTRACT

This guide provides users with a basic understanding of where and how the sun works in relation to a building and site and provides a simplified method of calculating sun angles and the available heat energy from the sun on vertical and horizontal surfaces. (Author/IRT)

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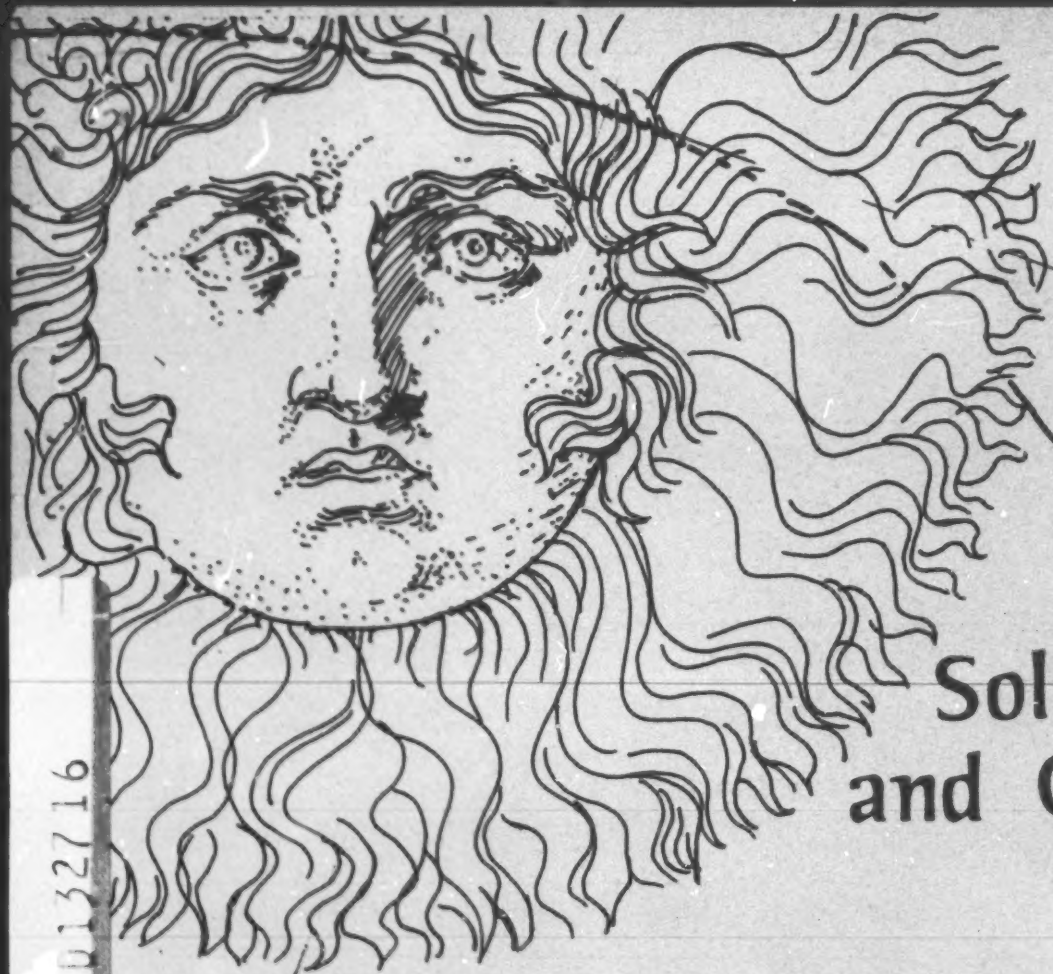

Solar Guide and Calculator

ED132716

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The Center for Environmental Research
School of Architecture and Allied Arts
University of Oregon
Eugene, Oregon 97403

SOLAR CALCULATOR

(44° N. LATITUDE)

The primary intent of this simplified user's solar guide is to:

1) Provide users with a basic understanding of where and how the sun works in relation to a building and site.

2) Provide users with a simplified method of calculating sun angles and the available heat energy from the sun on vertical and horizontal surfaces.

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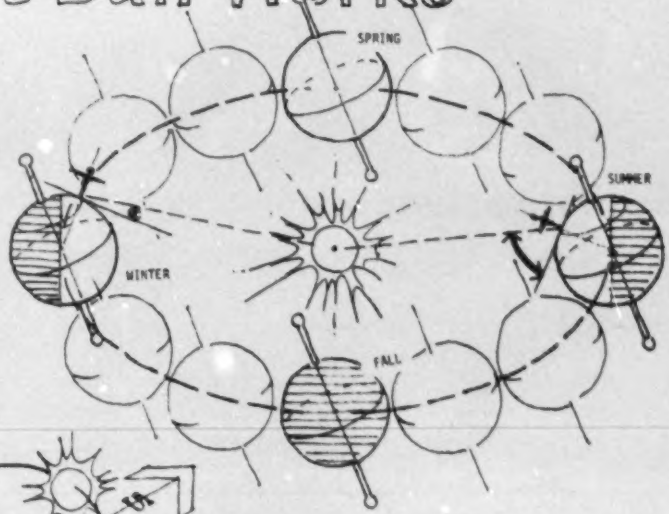
This is the first working draft of a more comprehensive user solar guide being developed by Edward Mazria and David Winitzky (June 1976).

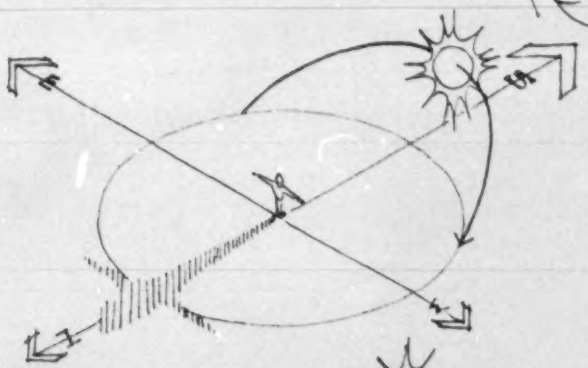
Portions of the text of this guide come from: 1) Solar Energy in Pacific Northwest Buildings, John Reynolds; 2) Solar Energy Workbook, Edward Mazria; and 3) The Impact of Solar Energy on Architecture, Robert Gray. The computer data used in developing the sun chart and solar intensity mask was supplied by Steven Baker.

A. How the Sun Works

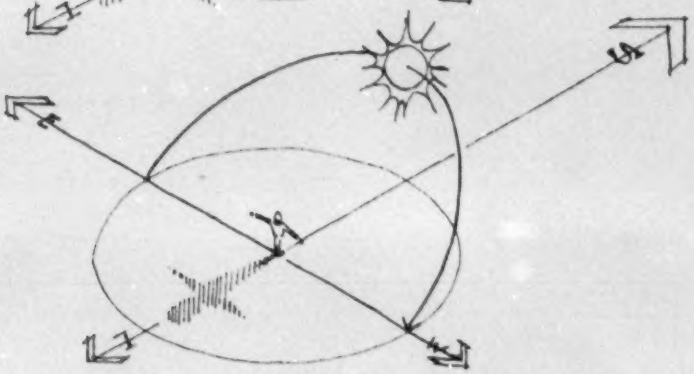
earth's orbit

As every modern person knows, the sun is at the center of the solar system, the earth moves in a circular orbit around the sun in a years time, the earth is spherical in shape and rotates on its axis once a day, and this axis is tilted at twenty-two and one-half degrees away from vertical to the plane of the earth's orbit around the sun. This tilt, causes a given point on the earth's surface to receive different amounts of solar energy at different times of the year which causes the seasons and their changes in temperature.

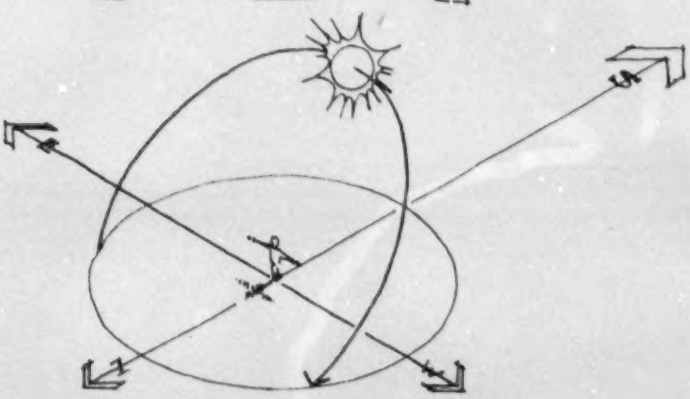




winter



spring & fall



summer

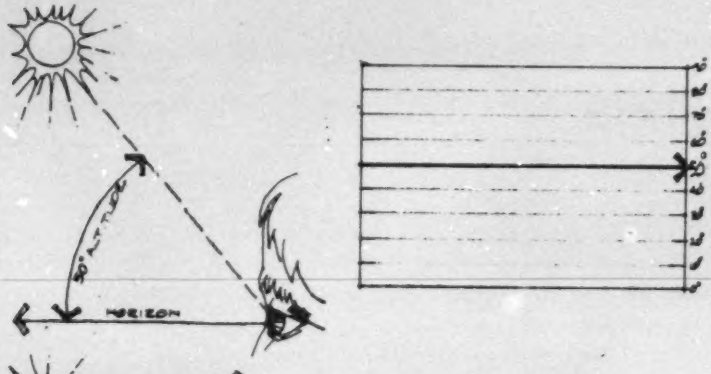
B. The Sun Chart

In order to understand and be responsive to the effects of the sun on the location and design of places, it is necessary to know, at any given moment, the sun's position in the sky. This information is necessary in order to calculate solar heat gain, and in locating buildings, outdoor spaces, interior room arrangements, windows, shading devices, vegetation and solar collectors. The chart which is developed here provides a convenient way of locating the sun for 44° N. latitude at any time and date. The following is a sequential description of how the sun chart was developed. It is included here to provide basic solar background information.

Two coordinates are needed to locate the position of the sun in the sky. They are called the altitude and the azimuth (also called the bearing angle).

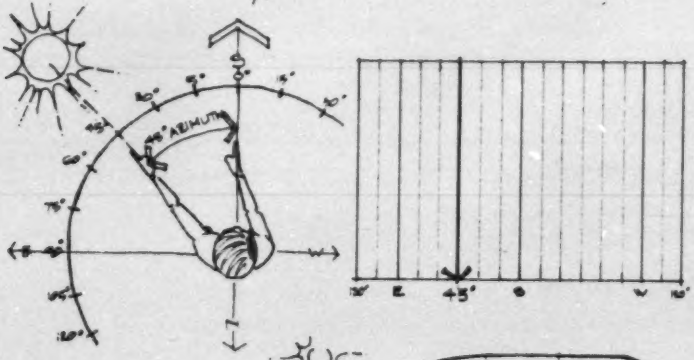
altitude

Solar altitude is the angle, above the horizon, of the position of the sun measured from the horizon. The horizontal lines on the chart represent altitude angles in 10° increments above the horizon.



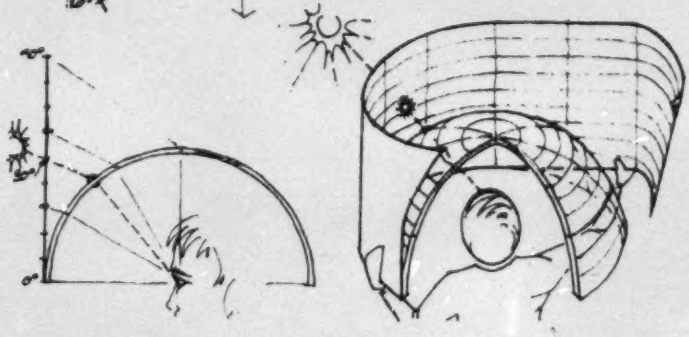
azimuth

Solar azimuth is the angle, along the horizon, of the position of the sun measured to the east of west from true south. The declination map on page 4 provides the magnetic variations for true south for locations within the United States.



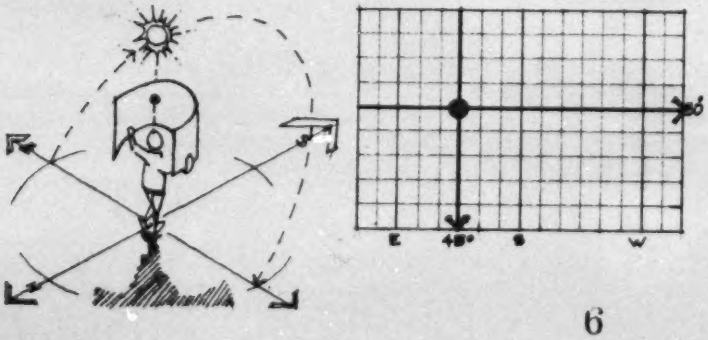
skydome

So, the grid on the chart represents vertical and horizontal angles of the whole skydome. It is as if there was a clear dome around the observer, and then the chart was peeled off of this dome and laid flat.

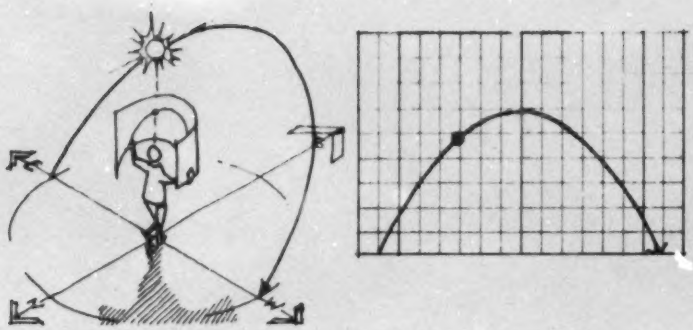


sun position

With the altitude and azimuth angles, the sun can be located at any point in the sky.

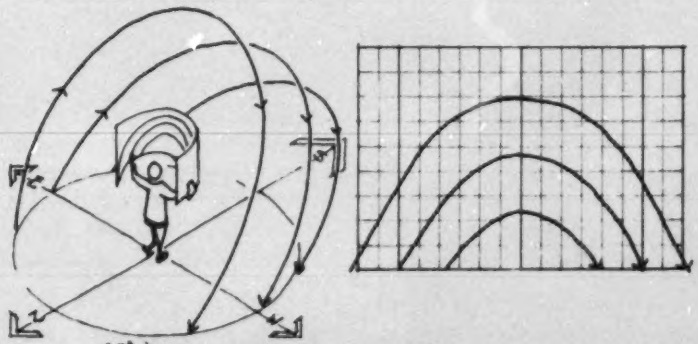


sun path



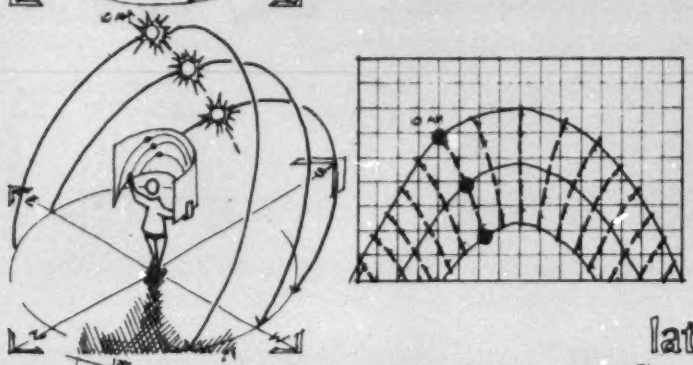
By connecting the points of the location of the sun throughout various times of the day, the sun's path for that day can be drawn.

seasonal paths



Thus, we can plot the sun's path for any day of the year. Those path's shown represent summer, fall/spring, and winter. The sun path is greatest during the summer when it reaches it's highest altitude and rises and sets with the widest azimuth angle from true south. During winter, the sun is much lower in the sky and rises and sets with the narrowest azimuth angles from true south.

times of day



Finally, if we connect the hour lines on each path, we get the heavy dotted line which represents the hours of the day. This completes the sun chart.

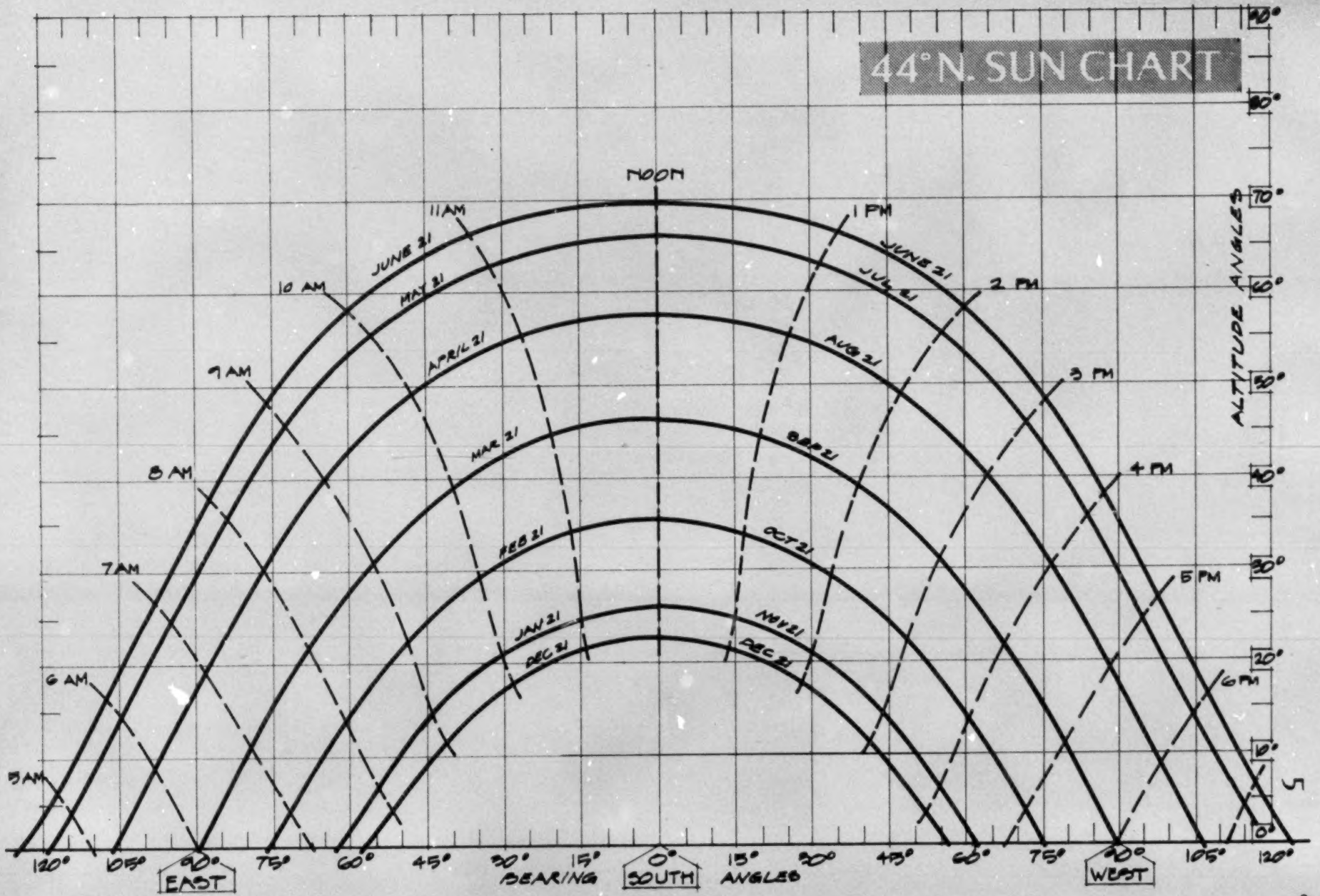
NOTE: The times on the sun chart are for solar time. This may vary from standard time as much as an hour and fifteen minutes for different locations and different times of the year. This is alright for most practical uses of the sun chart. It is important to remember to at least use standard time when using the charts.

latitude & declination

These paths vary according to site locations on the earth's surface by latitude, i.e., a different sun chart is required for different latitudes. Only the sun chart for 44° N. latitude is included in the guide. The map to the left will assist users in understanding which areas within the United States will use the 44° N. latitude sun chart.

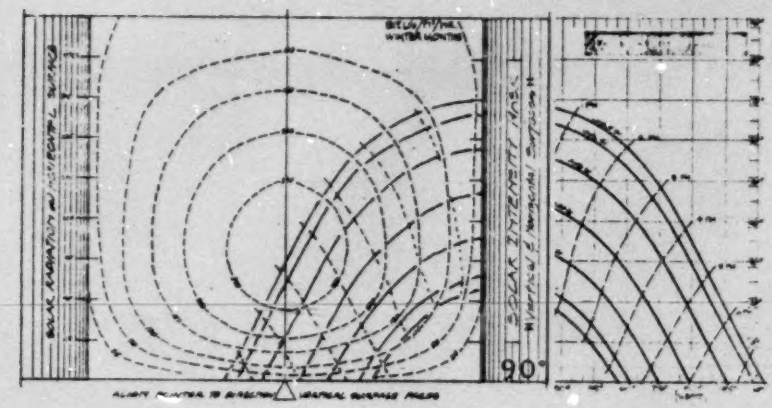
The map also shows the magnetic compass variations (declinations) for your area. It is necessary to adjust your compass reading by a few degrees east or west to obtain true south. The heavy broken lines on this map connect points of equal magnetic variation, and present a generalized picture of the magnetic variations. Due to "local attraction," it may be quite different for your specific locality. This chart is accurate enough for most uses of the sun chart; for more exact information, consult a local surveyor.

Libby Owens Ford - Sun Angle Calculator, 1975, p.25.

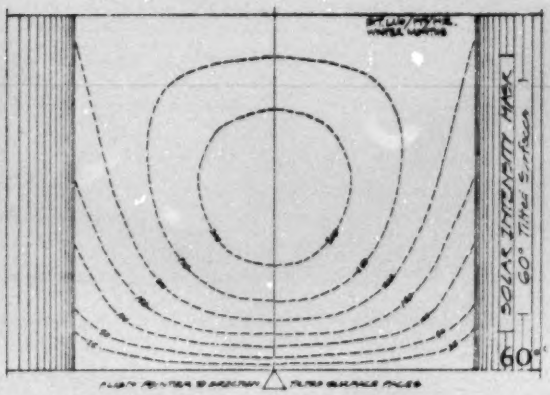

44° N. SUN CHART
NOON
11 AM
10 AM
9 AM
8 AM
7 AM
6 AM
5 AM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
JUNE 21
MAY 21
APRIL 21
MAR 21
FEB 21
JAN 21
DEC 21
JULY 21
AUG 21
SEPT 21
OCT 21
NOV 21
DEC 21
ALTITUDE ANGLES
80°
70°
60°
50°
40°
30°
20°
10°
0°
120° 105° 90° 75° 60° 45° 30° 15° 0° 15° 30° 45° 60° 75° 90° 105° 120°
EAST
BEARING
SOUTH
ANGLES
WEST

C. The Solar Intensity Masks[6]

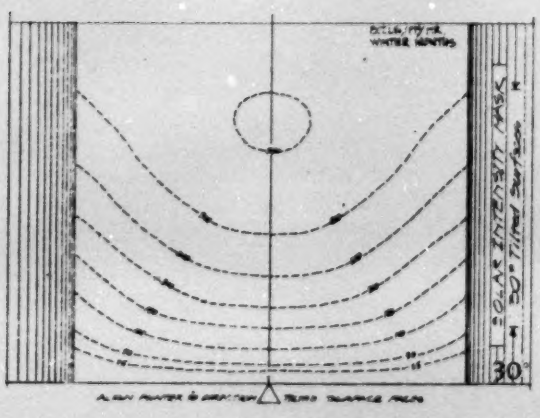
vertical and horizontal surfaces

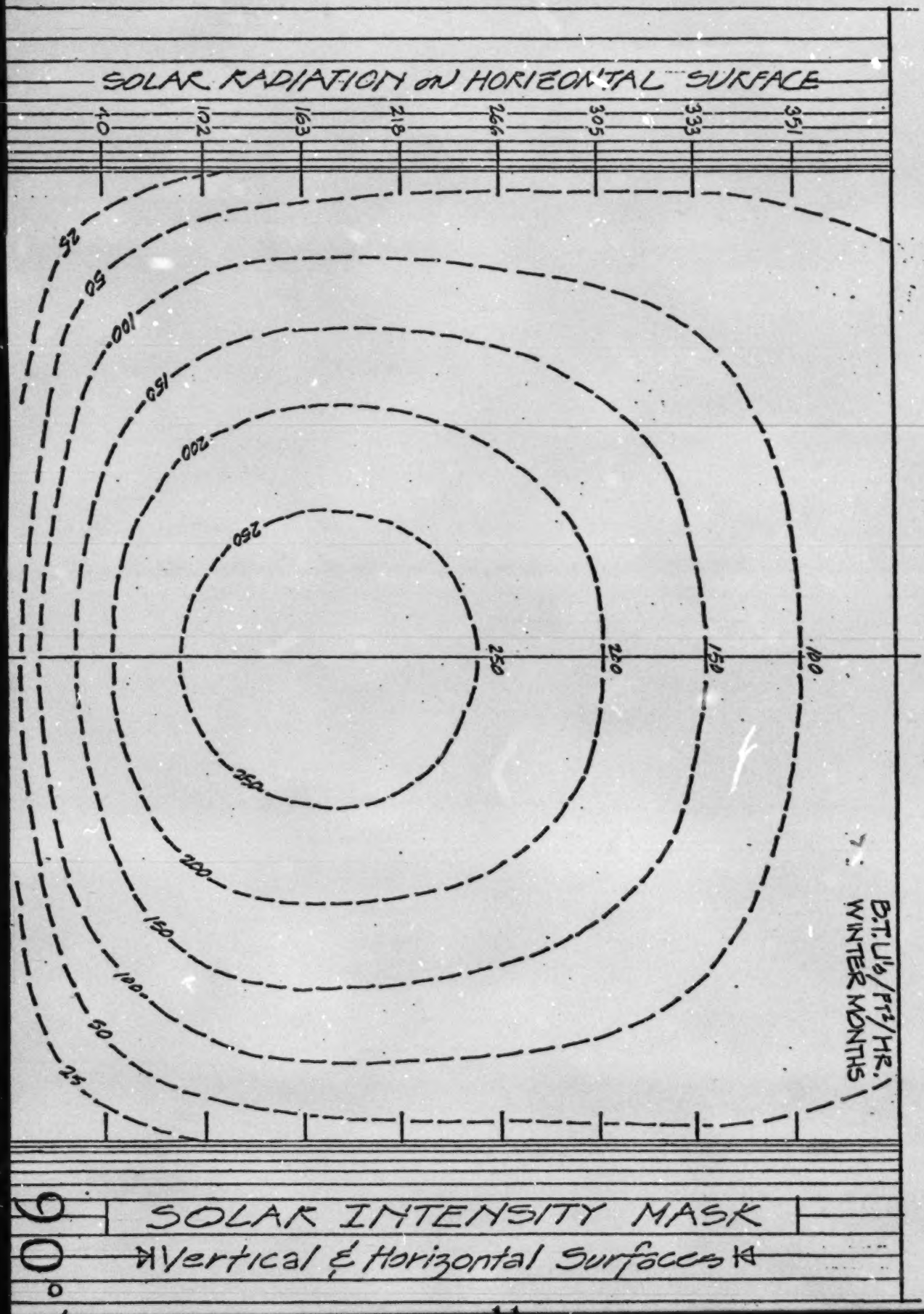


60° inclined surfaces



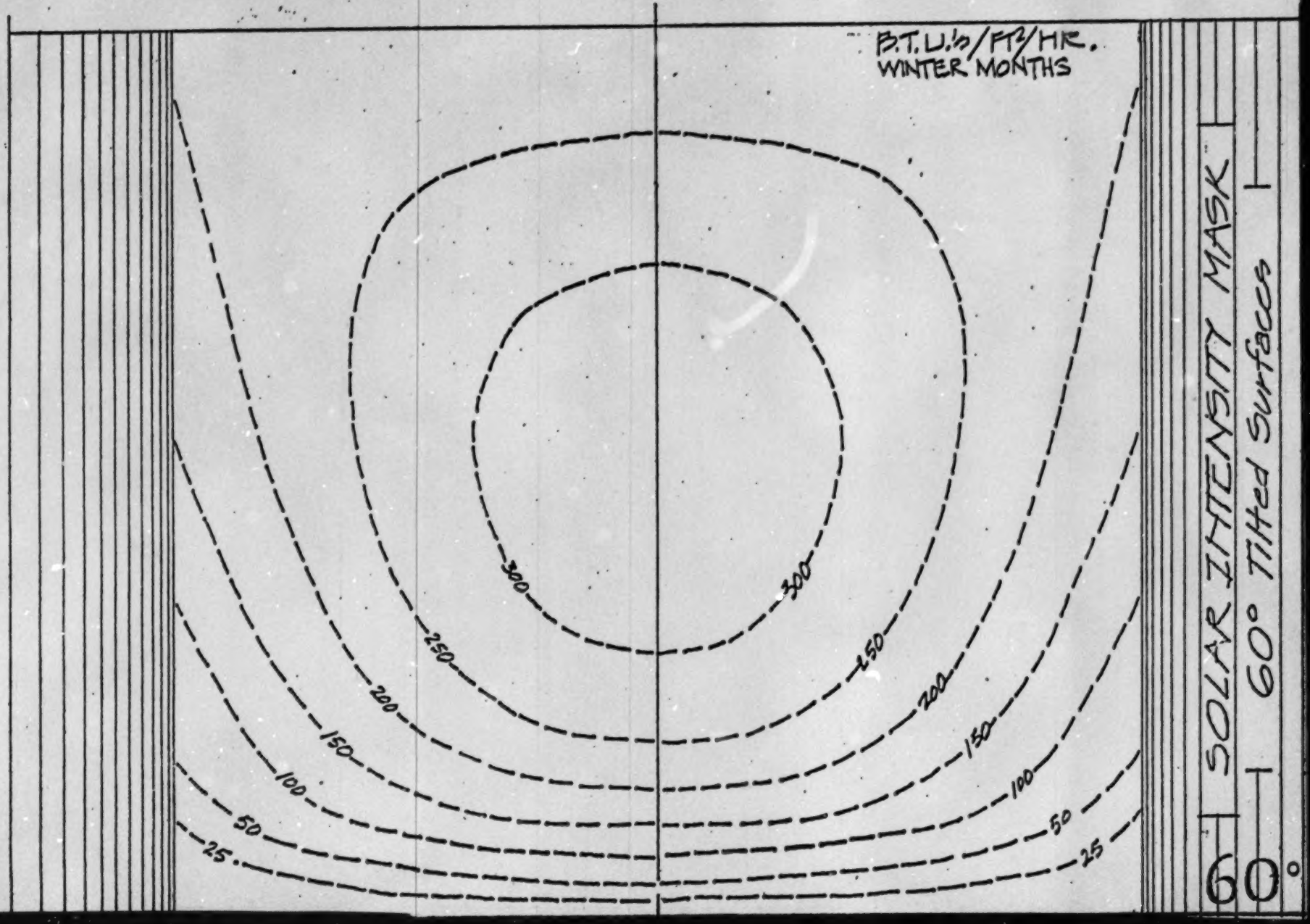
30° inclined surfaces

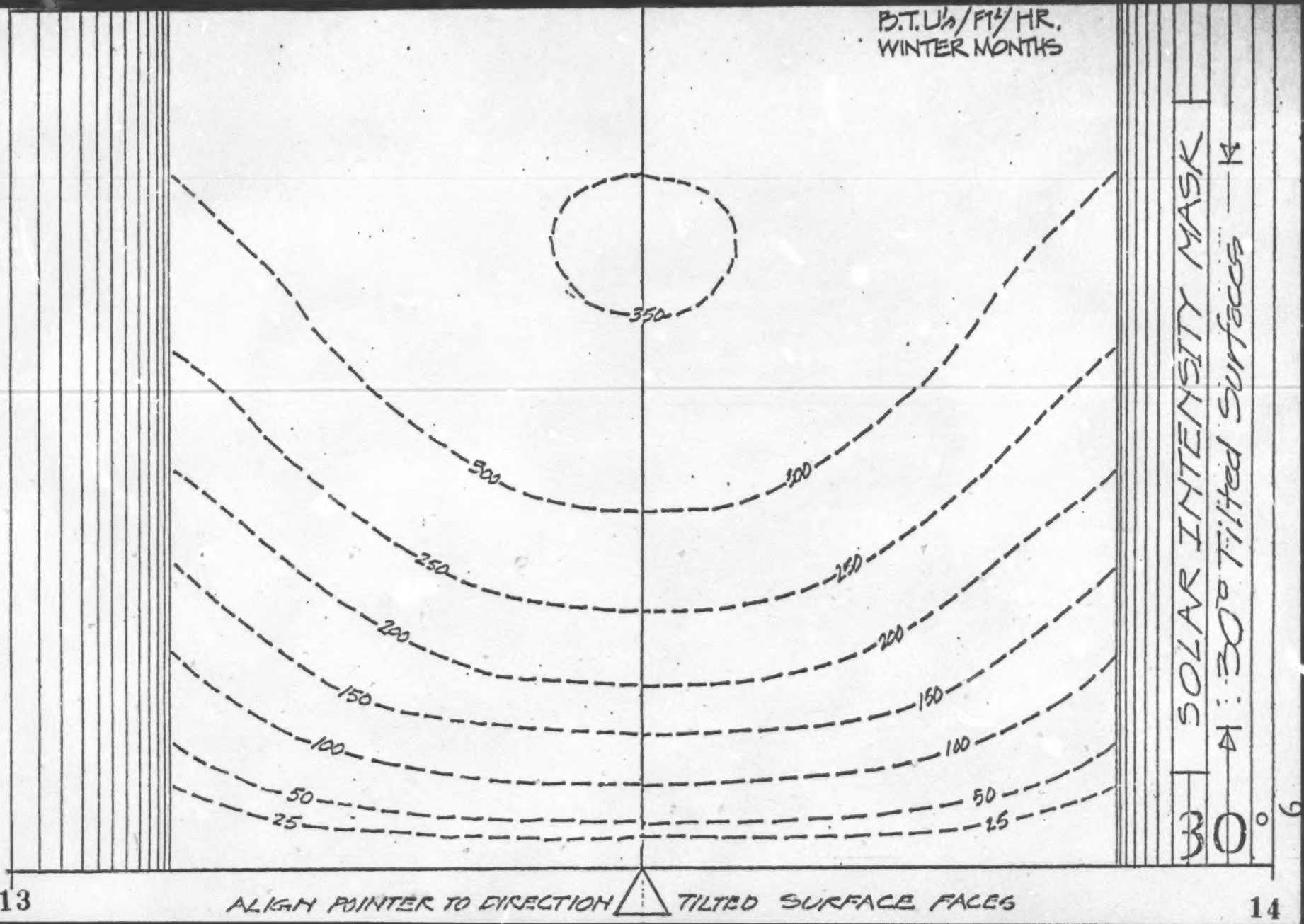




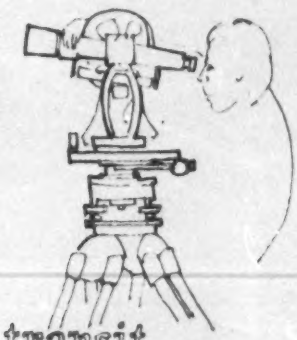
SOLAR INTENSITY MASK

Vertical & Horizontal Surfaces


B.T.U.'s/FT²/HR.
WINTER MONTHS
300
300
250
150
200
200
150
150
100
100
50
50
25
25
SOLAR INTENSITY MASK
60° Tilted Surfaces
60
0
0

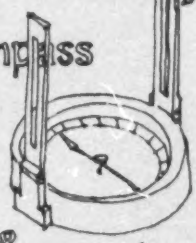

B.T.U.'s/FT²/HR.
WINTER MONTHS
350
300
250
200
150
100
50
25
SOLAR INTENSITY MASK
SCALE: 1/4" = 30°
ALIGN POINTER TO DIRECTION
TILTED SURFACE FACES

D. Plotting the Skyline

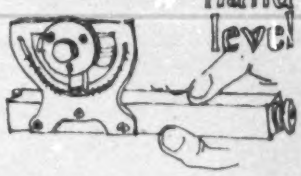


transit

or



&

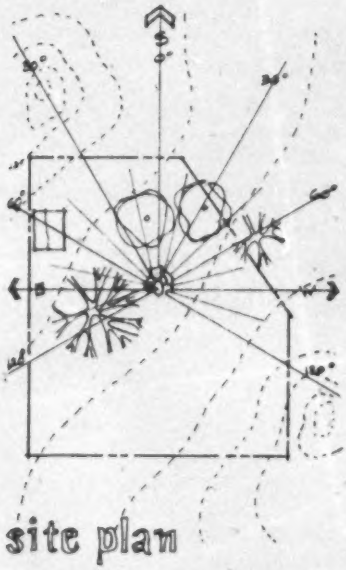


To find the amount of direct sun that any point on your site receives, it is necessary to plot obstructions which block the sun as seen from that point. We call this plotting the "skyline" and it is done in a similar way in which we plotted the sun's path. If the skyline is low, that is with no tall trees, adjacent buildings, abruptly rising hills, or other obstructions, the following procedure is unnecessary as all the points on the site will receive sun.

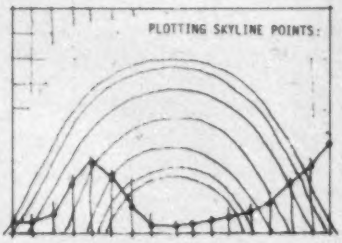
You will need: 1) a transit or compass for the bearing readings and a hand level for altitude readings, and

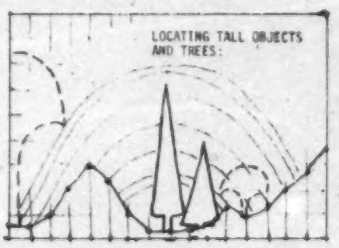
2) a copy of the sun chart for your location.

Place yourself at the approximate location where you wish to know the solar radiation. This may require a ladder if the location is on the second floor or roof of a building-to-be.



site plan





Find the altitude of the skyline as follows:

-- Determine which direction (bearing) is true south. (Remember magnetic variation; true south will be about 21° east of magnetic south in Eugene, Oregon.)

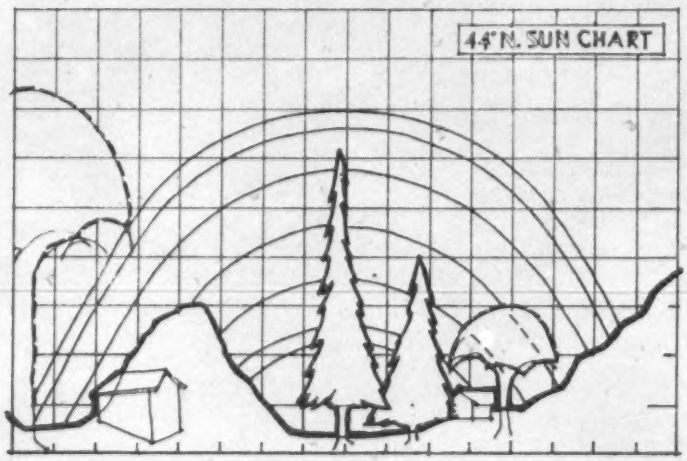
-- Aiming your level true south, determine the altitude (angle above the horizon) of the skyline. Plot this point on your chart above 0° true south.

-- Similarly, find and record the altitudes of skyline for each 15° bearing, both east and west of south, to at least 120°. This is a total of 17 altitude readings. Plot these readings for the respective bearing angles on the sun chart and connect them.

-- For isolated tall objects that block the sun such as tall evergreen trees, find both the bearing angle and the altitude for each object and record them at the appropriate point on the chart.

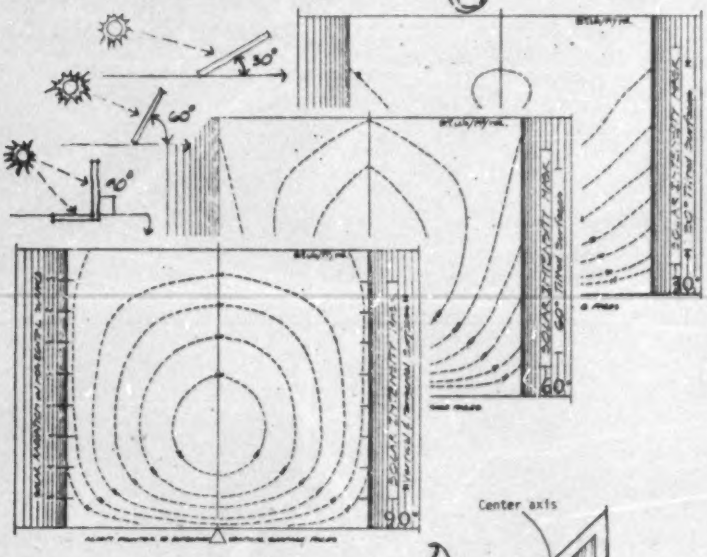
-- Finally, plot the deciduos trees in the skyline with a dotted line. These are of a special nature because they will block the sun during spring through fall and let most of the sun pass through when their leaves are gone, fall through spring.

This completes the skyline. The open areas on your completed chart are those times when you will get sun at that spot.



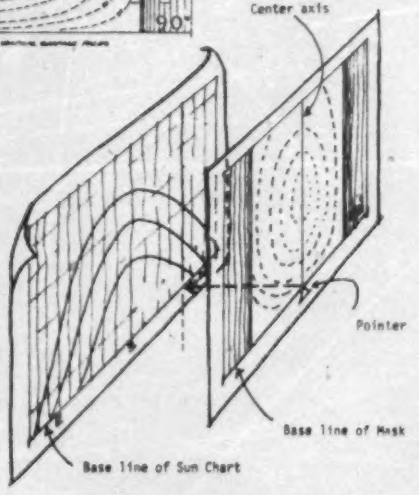
completed skyline

E. Calculating Solar Energy [11]



In the design of solar heating and cooling systems, it is important to know the amount of thermal radiation (sun's heat measured in BTU's) that strikes a surface at some particular time of the day, hour, or daily or monthly totals. This can all be determined by the use of the solar intensity masks which fit over and are used in conjunction with the Sun Chart. The mask marked "90°" is for vertical and horizontal surfaces, mask "60°" for inclined surfaces of 60°, and likewise, mask "30°" for inclined surfaces of 30° (as measured from the horizon).

The solar intensity masks have a center axis and base line which are used for alignment with the Sun Chart. To align the mask for a particular surface, determine the direction the surface is facing and set the center axis of the mask on the bearing angle (the direction the surface is facing) of the Sun Chart. Keep the base line directly over the base line of the Sun Chart. You are now ready to determine the solar intensity values for that surface.



ALIGNMENT EXAMPLE:

Vertical Surface facing 45° west of south:

Set the pointer on the intensity mask to line up with 45° west on the base-line of the Sun Chart. Be sure that the base lines of both sheets are in line.

-- Mask and Sun Chart are now aligned to read solar intensity values.

hourly totals

To determine the clear day hourly totals of heat energy striking a surface:

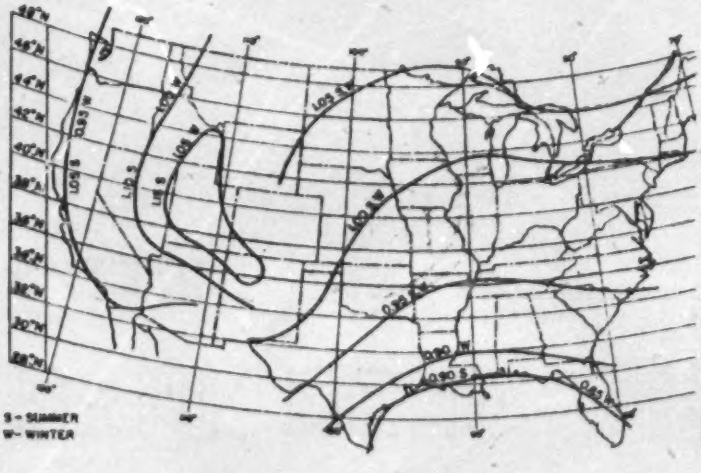
1)-- Select the proper mask based on the surface slope.

2)-- Align the mask on the Sun Chart based on the orientation of the surface to the east or west of south.

3)-- Select the month when you want the reading and use that sun path to read the values.

4)-- Select the hour and month in which you want the reading: the intersection of the hour line and the sun path will locate the position of the sun. Read the number of BTU's for that sun's position from the radiation mask - if the point where you want the reading falls between radiation lines, interpolate to find the value.

NOTE: This clear day number needs to be adjusted depending on your location in the U.S. Find the line which is closest to your area on the map below. S is for summer adjustment numbers, and W is for winter adjustment numbers. Multiply the clear day totals from the mask by these adjustment numbers.



daily totals

To determine the total daily amount of heat energy striking a surface:

-- Simply follow the procedure for the hourly totals for each hour of the day and total these to get the daily total. If the hourly totals have not been adjusted for your area, then adjust the daily total by multiplying it by appropriate adjustment factor from the map.

Threskeld and Jordan, Transactions of The American Society of Heating and Air Conditioning Engineers, 1968, v.64.

SUN CHARTS

for

28°NL, 32°NL, 36°NL, 40°NL and 48°NL

A

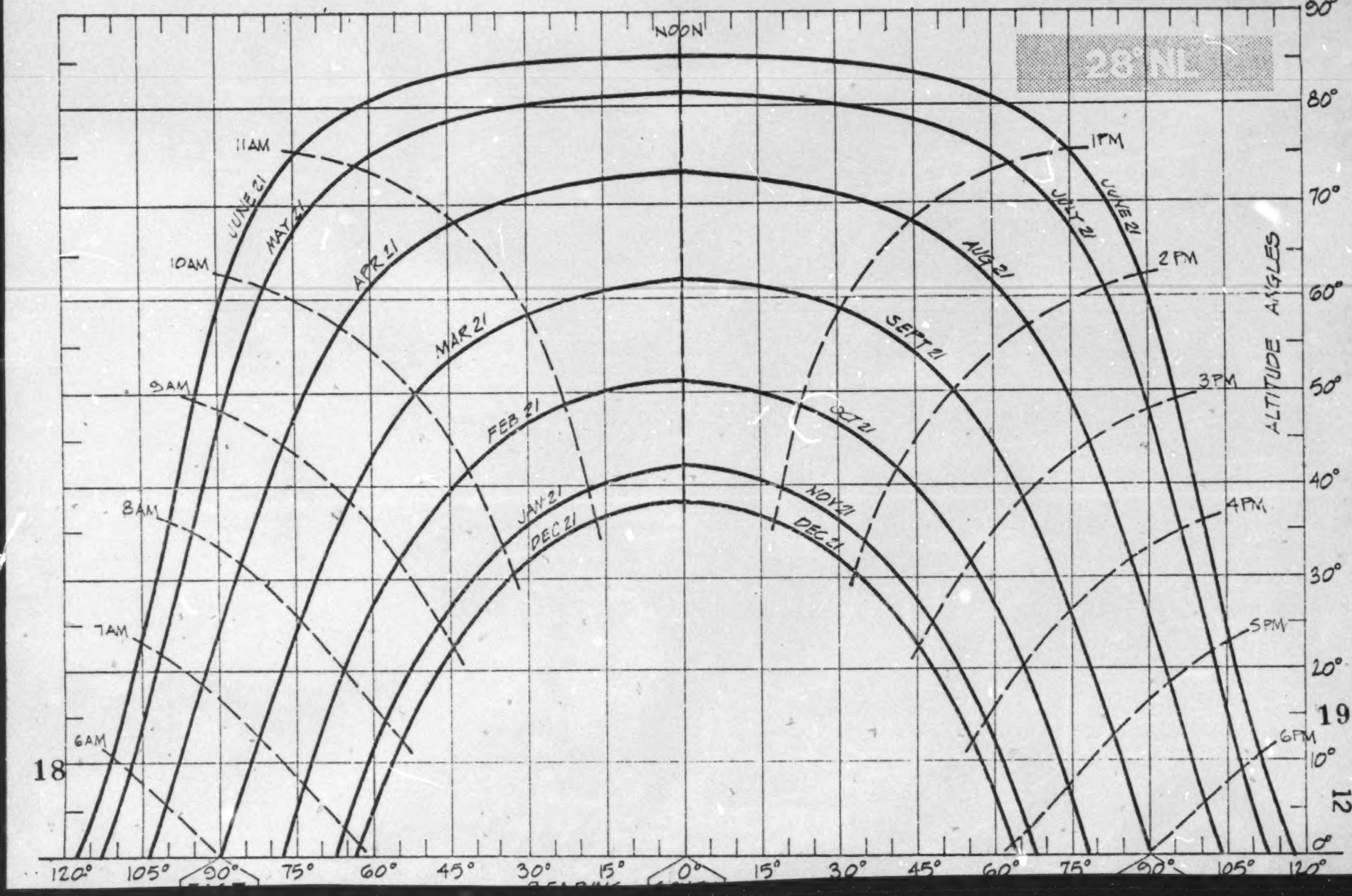
SUPPLEMENT

to the

SOLAR GUIDE AND CALCULATOR

Edward Mazria

Eugene, Oregon


28° NL
NOON
11AM
10AM
9AM
8AM
7AM
6AM
1PM
2PM
3PM
4PM
5PM
6PM
JUNE 21
MAY 21
APR 21
MAR 21
FEB 21
JAN 21
DEC 21
JULY 21
AUG 21
SEPT 21
OCT 21
NOV 21
DEC 21
ALTITUDE ANGLES
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
120°
105°
90°
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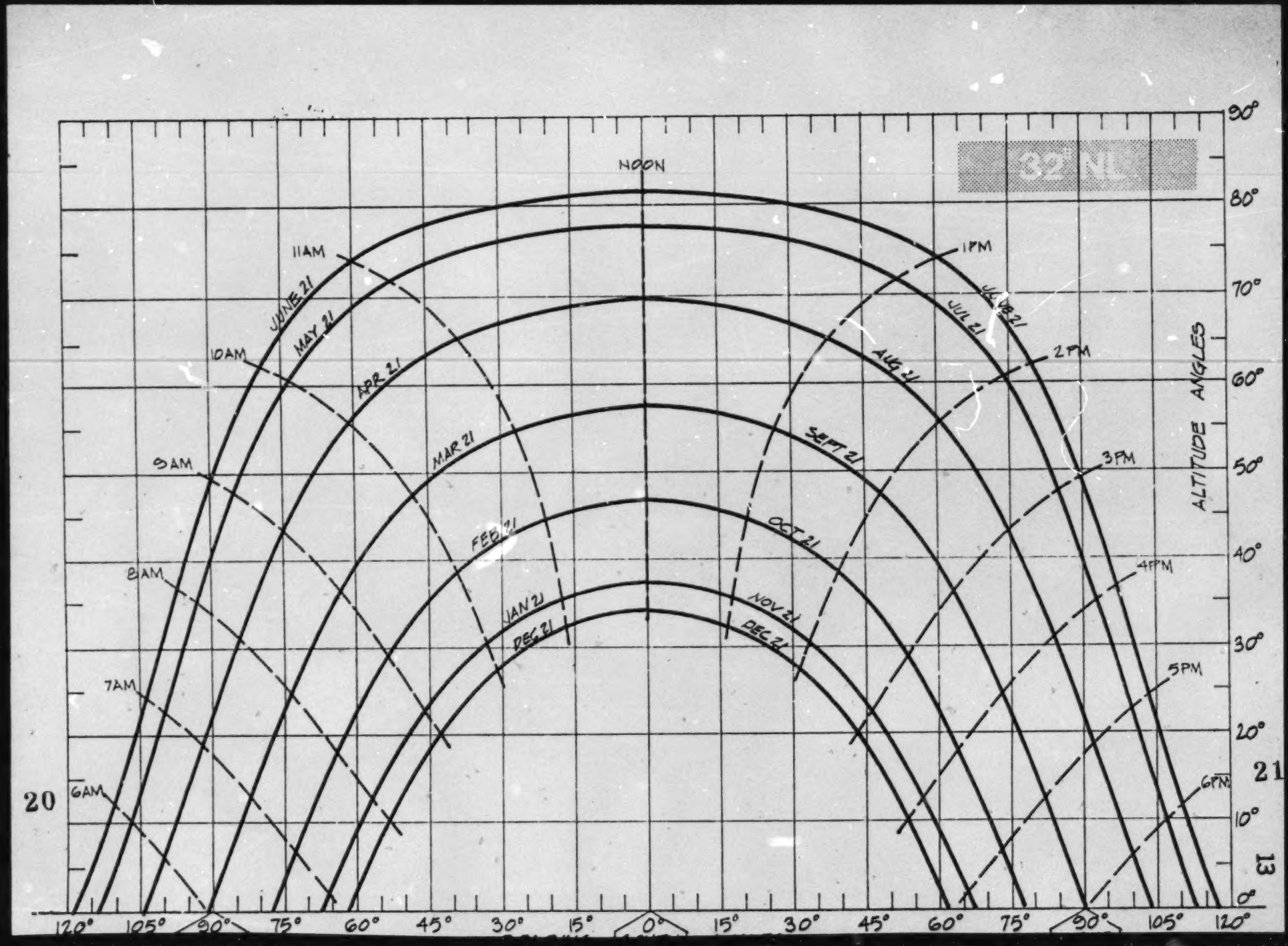
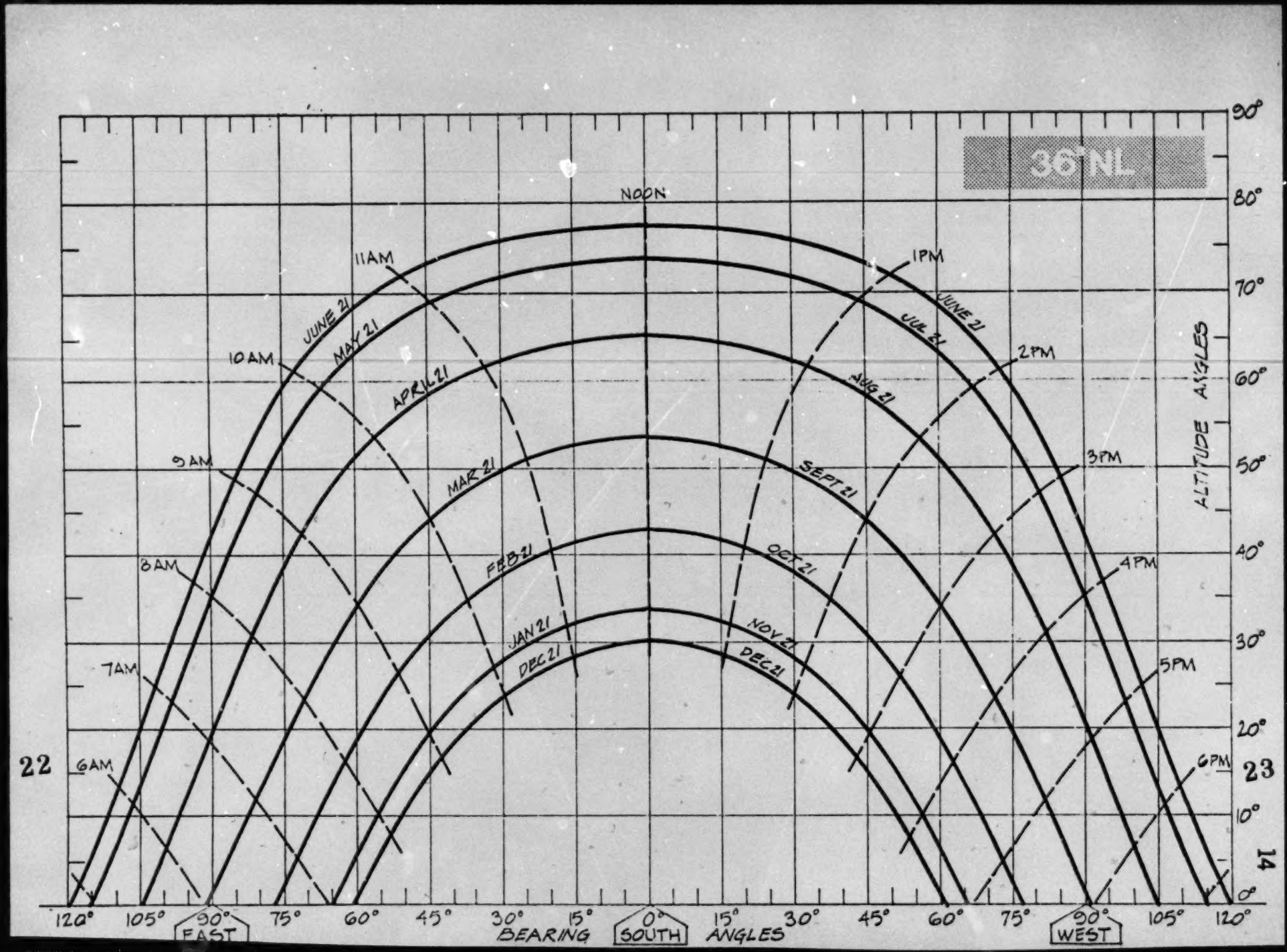
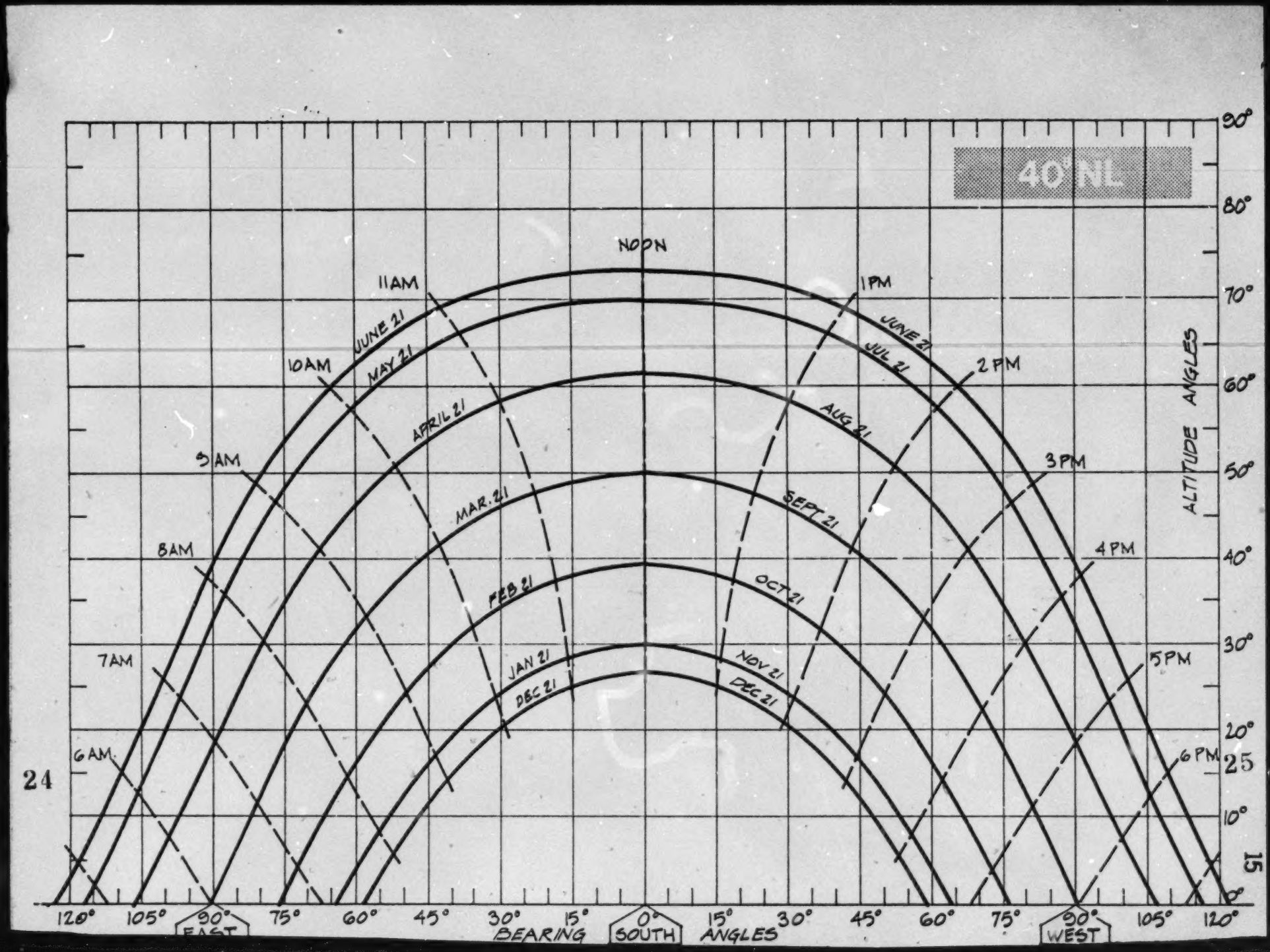
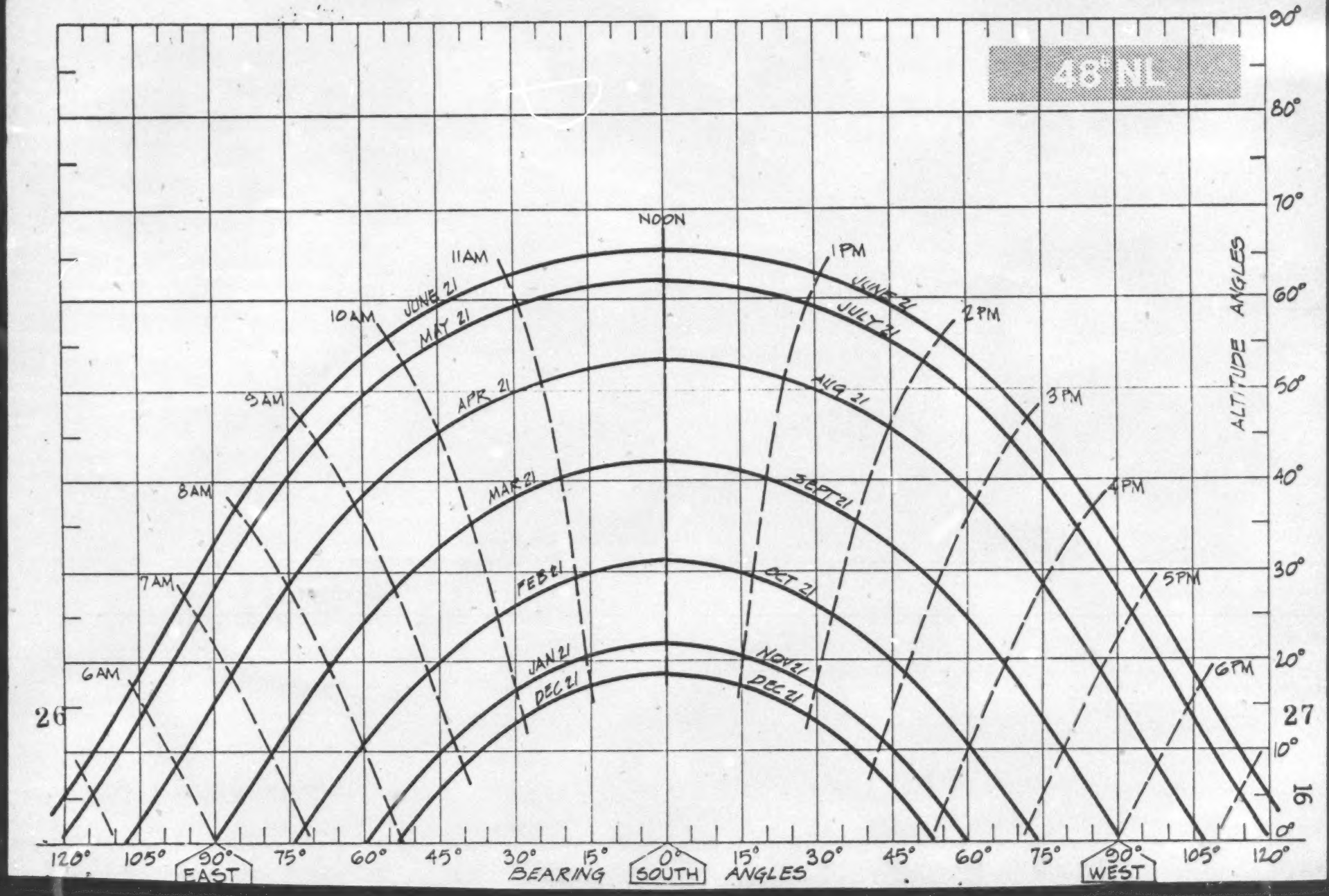
60°
75°
90°
105°
120°


32 NL
NOON
11AM
10AM
9AM
8AM
7AM
6AM
1PM
2PM
3PM
4PM
5PM
6PM
JUNE 21
MAY 21
APR 21
MAR 21
FEB 21
JAN 21
DEC 21
JULY 21
JUL 21
AUG 21
SEPT 21
OCT 21
NOV 21
DEC 21
ALTITUDE ANGLES
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
120° 105° 90° 75° 60° 45° 30° 15° 0° 15° 30° 45° 60° 75° 90° 105° 120°
20
21
13


36°NL
NOON
11AM
1PM
10AM
2PM
9AM
3PM
8AM
4PM
7AM
5PM
6AM
6PM
JUNE 21
MAY 21
APRIL 21
MAR 21
FEB 21
JAN 21
DEC 21
JUNE 21
JUL 21
AUG 21
SEPT 21
OCT 21
NOV 21
DEC 21
ALTITUDE ANGLES
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
120° 105° 90° 75° 60° 45° 30° 15° 0° 15° 30° 45° 60° 75° 90° 105° 120°
EAST
BEARING ANGLES
SOUTH
WEST


40° NL
NOON
11AM
1PM
10AM
2PM
9AM
3PM
8AM
4PM
7AM
5PM
6AM
6PM
JUNE 21
MAY 21
APRIL 21
MAR. 21
FEB 21
JAN 21
DEC 21
JUNE 21
JUL 21
AUG 21
SEPT 21
OCT 21
NOV 21
DEC 21
ALTITUDE ANGLES
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
120° 105° 90° EAST 75° 60° 45° 30° 15° 0° SOUTH 15° 30° 45° 60° 75° 90° WEST 105° 120°
BEARING ANGLES


48° NL
NOON
11AM
1PM
10AM
2PM
9AM
3PM
8AM
4PM
7AM
5PM
6AM
6PM
JUNE 21
MAY 21
APR 21
MAR 21
FEB 21
JAN 21
DEC 21
JULY 21
AUG 21
SEPT 21
OCT 21
NOV 21
DEC 21
ALTITUDE ANGLES
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
120° 105° 90° 75° 60° 45° 30° 15° 0° 15° 30° 45° 60° 75° 90° 105° 120°
EAST
BEARING
SOUTH
ANGLES
WEST